The CRP increases soil organic carbon

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ABSTRACT: The land use change from cropland to perennial grass cover associated with the Conservation Reserve Program (CRP) may sequester atmospheric CO_2 back into the soil carbon pool, thereby changing formerly cultivated soils from sources to sinks for atmospheric carbon. To evaluate the effect of CRP on soil organic carbon (SOC) levels, samples from adjacent cropland, native pasture, and five year old CRP sites in Texas, Kansas, and Nebraska were analyzed. Across all locations, SOC levels for cropland, CRP, and native pasture were 59.2, 65.1, and 90.8 metric tons C ha^{-1} in the surface 300 cm, respectively. CRP lands gained an average of 1.1 tons C ha^{-1} yr^{-1} suggesting that the 17 million hectares of land enrolled in CRP may have the potential to sequester about 45% of the 38.1 million tons of carbon released annually into the atmosphere from U.S. agriculture. These findings illustrate that agricultural CO_2 emissions may be effectively controlled through changes in land use and management systems.

Many Great Plains soils have declined in organic carbon (C) content and nutrient supplying capacity since they were initially cultivated. Haas et al. (*13*) summarized early studies documenting the effects of cultivation on soil carbon and nitrogen from 24 Great Plains Research Stations and reported losses of 24 to 60% from soils cultivated 30 to 43 years. More recent studies from the Great Plains (*1,3,6,10,16,17,24,25*) report similar losses of soil organic carbon (SOC) with cultivation. Current estimates (*7*) suggest that cultivated croplands in the United States lose about 2.7 million metric tons C yr^{-1} (6 billion lbs C yr^{-1}). An additional 35.4 million metric tons C (78 billion lbs C) are released to the atmosphere every year from agricultural fossil fuel use and manufacture of nitrogen fertilizers (*7*). These data indicate that agricultural activities are significant contributors of CO_2 gas to the atmosphere.

One of the major goals of the Conservation Reserve Program (CRP) is to reduce water and wind erosion through the establishment of perennial grass cover on more than 17 million ha (45 million ac) of highly erodible and environmentally sensitive croplands (*14*). Once established, however, these new grasslands also may have the potential to concomitantly reduce atmospheric CO_2 levels and increase SOC levels due to accumulation and incorporation of litter into surface soils and the relatively large amounts of net primary production allocated toward root growth in grasslands (*2,7*). McConnell and Quinn (*18*) showed that SOC contents of the surface 0 to 25 cm (0 to 10 in) of croplands abandoned and/or reseeded to perennial grasses were similar to adjacent native rangeland following about 50 years of recovery. Conversely, surface SOC of cropland continually cultivated was substantially lower than that of native rangeland and abandoned and reseeded cropland. Dormaar and Smoliak (*12*) observed similar trends for abandoned cropland and native rangeland in Alberta, Canada, and suggested that more than 55 years are required for SOC in revegetated, abandoned croplands to approach that of native rangeland. Based on these results, the land use change from crop production to perennial grass cover associated with CRP may sequester atmospheric carbon back into the soil carbon pool, thereby changing soils from sources to sinks for atmospheric carbon. The objective of this research was to assess changes in SOC levels associated with five year old CRP plantings at selected Great Plains locations.

Materials and methods

With assistance from area Soil Conservation Service personnel, we identified and selected five locations within the Great Plains where adjacent, similarly mapped and classified cropland, native pasture, and five-year-old CRP sites could be sampled. These locations were near Big Spring and Seminole, Texas, Colby and Atwood, Kansas, and Valentine, Nebraska. With respect to land use and cropping history, cropland and CRP land at each location were similar to one another prior to CRP initiation. The native pasture soils were used as benchmarks against which losses of SOC due to cultivation could be compared. Cropland soils were used as benchmarks against which gains of SOC due to CRP could be compared.

The Big Spring and Seminole, Texas, locations occurred on Patricia fine sands (fine-loamy, mixed, thermic Aridic Paleustalf) with 0 to 3% slopes. Average annual precipitation is about 430 mm (17 in) with 75% of this occurring between May and October. Cropland and CRP land at Big Spring and Seminole were initially plowed and cropped to cotton (*Gossypium hirsutum* L.) in 1958 and 1963, respectively. In 1987, CRP land at both locations was removed from cotton production and seeded to weeping lovegrass [*Eragrostis curvula* (Schrad.) Nees.]. Native pastures at both locations have supported moderate year long cattle grazing for more than 40 years and are dominated by sand dropseed [*Sporobolus cryptandrus* (Torr.) A. Gray], little bluestem [*Schizachyrium scoparium* (Michx.) Nash], perennial threeawn (*Aristida* spp.), shin oak (*Quercus havardii* Rydb.), and blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex. Steud.]. Forage production estimates from native pastures and CRP sites at both locations ranged from 800 to 1100 kg ha^{-1} (700 to 1000 lbs ac^{-1}) in 1992.

The Colby and Atwood, Kansas, locations occurred on Ulysses silt loams (fine-silty, mixed, mesic Aridic Haplustoll) with 1 to 3% slopes. Average annual precipitation is about 500 mm (20 in) with 76% of this occurring between

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The authors thank Dennis Williamson, Bobby Tricks, Susan Oldfather, Jan Joseph, and, especially, Mark Dumesnil for assistance in site selection and field sampling.

J. Soil and Water Cons. 49 (5) 488-492

Reprinted from the *Journal of Soil and Water Conservation*
September-October 1994, Volume 49, Number 5

Table 1. Mean organic carbon contents of the 0 to 20 cm soil profile under three contrasting land uses at selected Great Plains locations (Values in parentheses represent mean percentage organic carbon)

Depth (cm)	Location	Crops	CRP	Native Pasture
		Land Use		
		Metric tons C ha^{-1}		
0 to 5	Atwood	6.4(0.88)*	7.3(1.04)	17.1(2.44)
	Colby	7.2(1.01)*	11.4(1.66)	12.6(1.81)
	Big Spring	0.6(0.07)*	0.8(0.10)	2.5(0.32)
	Seminole	0.7(0.09)	0.9(0.12)	4.7(0.61)
	Valentine	4.0(0.54)*	4.7(0.62)	10.6(1.41)
	Mean	3.8(0.52)*	5.0(0.71)	9.5(1.31)
5 to 10	Atwood	6.1(0.85)	6.4(0.91)	11.2(1.58)
	Colby	6.5(0.92)	8.8(1.27)	9.2(1.32)
	Big Spring	0.6(0.08)*	0.8(0.10)	1.8(0.23)
	Seminole	0.7(0.09)	0.7(0.09)	2.6(0.34)
	Valentine	3.1(0.41)*	3.8(0.49)	7.7(1.03)
	Mean	3.4(0.47)*	4.1(0.57)	6.5(0.90)
10 to 15	Atwood	4.9(0.10)	5.1(0.14)	8.7(1.28)
	Colby	5.3(0.76)*	6.7(0.97)	7.6(1.11)
	Big Spring	0.6(0.08)*	0.7(0.09)	1.7(0.21)
	Seminole	0.7(0.09)	0.6(0.07)	2.2(0.27)
	Valentine	3.4(0.46)	3.6(0.48)	5.2(0.68)
	Mean	3.0(0.42)	3.3(0.47)	5.1(0.71)
15 to 20	Atwood	4.3(0.63)*	4.9(0.72)	7.9(1.18)
	Colby	4.2(0.62)*	5.5(0.82)	6.5(0.94)
	Big Spring	0.6(0.08)*	0.8(0.10)	1.7(0.21)
	Seminole	0.6(0.08)	0.6(0.08)	1.6(0.20)
	Valentine	3.4(0.45)	3.5(0.46)	4.7(0.61)
	Mean	2.6(0.37)*	3.0(0.44)	4.5(0.63)

* Indicates differences in soil organic carbon between cropland and CRP are significant at $P \leq 0.10$ as determined by paired t-tests. All differences in soil organic carbon between cropland and native pasture are significant at $P \leq 0.10$, and all differences in soil organic carbon between CRP and native pasture except the 0 to 5 cm increment at Colby are significant at $P \leq 0.10$ as determined by paired t-tests.

April and September. Cropland and CRP land at Colby and Atwood were initially plowed and cropped to a wheat (*Triticum aestivum* L.)-fallow rotation in the late 1930s. In 1987, CRP land at both locations was removed from wheat production and seeded to a native mixture containing blue grama, indiangrass [*Sorgastrum nutans* (L.) Nash], little bluestem, big bluestem (Andropogon gerardi Vitman), and western wheatgrass [*Pascopyrum smithii* (Rydb.) A. Love]. Native pastures at both locations are dominated by blue grama, western wheatgrass, sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], little bluestem, and buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.] and have supported spring-summer cattle grazing for more than 50 years. Forage production estimates from native pastures and CRP sites at both locations ranged from 2000 to 2200 kg ha^{-1} (1800 to 2000 lbs ac^{-1}) in 1992.

The Valentine location occurred on a Valentine fine sand (mixed, mesic Typic Ustipsamment) with 3 to 4% slopes. Average annual precipitation is about 480 mm (19 in) with 80% of this occurring between April and September. Cropland and CRP land at this location were originally plowed and cropped to an irrigated corn (*Zea mays* L.)-sorghum (*Sorghum bicolor* L.)-alfalfa (*Medicago sativa* L.) rotation in 1978. In 1987, CRP land was removed from the cropping rotation and seeded to a native mixture containing big bluestem, little bluestem, sand bluestem (*Andropogon hallii* Hack.), blue grama, sideoats grama, and switchgrass (*Panicum virgatum* L.). The native pasture has supported winter cattle grazing for more than 40 years and is dominated by little bluestem, sand bluestem, prairie sandreed [*Calamovilfa longifolia* (Hook) Scribn.], needle-and-thread (*Stipa comata* Trin. and Rupr.), and blue grama. Forage production on native pasture and CRP land during 1992 was estimated to range from 1100 to 1300 kg ha^{-1} (1000 to 1200 lbs ac^{-1}).

Soil samples from each location/land use combination were collected during the summer of 1992 using truck-mounted, hydraulically operated soil coring equipment. Field sampling consisted of collecting seven randomly located cores from each location/land use combination to a depth of 3 m (120 in). Plant litter was removed from the soil surface before each core was collected. An additional core was collected from each location/land use combination for bulk density analysis (*4*). These data were compared to additional bulk density data obtained from the National Soil Survey Laboratory, Lincoln, Nebraska, to reduce the uncertainty associated with using single cores to estimate bulk density. Differences in bulk

Table 2. Mean organic carbon contents of the 20 to 40 cm soil profiles under three contrasting land uses at selected Great Plains locations (Values in parentheses represent mean percentage organic carbon)

Depth (cm)	Location	Crops	CRP	Native Pasture
		Land Use		
		Metric tons C ha^{-1}		
20 to 30	Atwood	7.2(0.52)*	8.6(0.63)	13.6(1.00)
	Colby	7.7(0.57)*	9.6(0.71)	11.9(0.88)
	Big Spring	1.1(0.07)*	1.4(0.09)	3.5(0.22)
	Seminole	1.2(0.08)*	1.6(0.10)	2.6(0.16)
	Valentine	3.7(0.26)	4.2(0.29)	7.2(0.50)
	Mean	4.2(0.30)*	5.1(0.36)	7.8(0.55)
30 to 40	Atwood	5.8(0.47)	6.4(0.52)	9.5(0.77)
	Colby	8.1(0.63)*	8.9(0.70)	10.5(0.84)
	Big Spring	1.2(0.07)*	2.3(0.14)	3.7(0.23)
	Seminole	1.5(0.09)	1.3(0.08)	3.1(0.19)
	Valentine	2.9(0.19)	3.2(0.22)	6.8(0.46)
	Mean	3.9(0.29)*	4.4(0.34)	6.7(0.49)

* Indicates differences in soil organic carbon between cropland and CRP are significant at $P \leq 0.10$ as determined by paired t-tests. All differences in soil organic carbon between cropland and native pasture and CRP and native pasture are significant at $P \leq 0.10$ as determined by paired t-tests.

Table 3. Mean organic carbon contents of the 40 to 100 cm soil profiles under three contrasting land uses at selected Great Plains locations (Values in parentheses represent mean percent organic carbon)

		Land Use		
Depth (cm)	Location	Crops	CRP	Native pasture
		Metric tons C ha^{-1}		
40 to 60	Atwood	9.0(0.34)	9.0(0.34)	10.7(0.41)
	Colby	12.6(0.48)	14.5(0.56)	18.4(0.71)
	Big Spring	3.3(0.10)*	5.5(0.16)	9.7(0.29)
	Seminole	4.5(0.13)	4.1(0.12)	8.5(0.26)
	Valentine	4.7(0.16)	4.6(0.16)	9.7(0.33)
	Mean	6.8(0.24)	7.5(0.26)	11.4(0.40)
60 to 80	Atwood	6.2(0.23)	5.7(0.21)	6.7(0.26)
	Colby	8.3(0.32)	9.3(0.36)	13.7(0.52)
	Big Spring	4.2(0.12)*	5.8(0.17)	7.4(0.22)
	Seminole	4.3(0.12)*	5.0(0.15)	6.2(0.19)
	Valentine	2.8(0.10)*	3.9(0.14)	8.9(0.32)
	Mean	5.2(0.18)	5.9(0.21)	8.6(0.30)
80 to 100	Atwood	4.8(0.18)	5.2(0.19)	6.1(0.23)
	Colby	5.8(0.22)	6.5(0.25)	9.4(0.36)
	Big Spring	4.1(0.12)	4.2(0.13)	5.9(0.18)
	Seminole	4.0(0.12)	4.2(0.13)	5.1(0.15)
	Valentine	2.5(0.09)	3.2(0.11)	6.5(0.24)
	Mean	4.2(0.14)	4.6(0.16)	6.6(0.23)
0 to 100	Atwood	54.7	58.6	91.5
	Colby	65.7*	81.2	99.8
	Big Spring	16.3*	22.3	37.9
	Seminole	18.2	19.0	36.6
	Valentine	30.5	34.7	67.3
	Mean	37.1	43.1	66.7

* Indicates differences in soil organic carbon between cropland and CRP are significant at $P \leq 0.10$ as determined by paired t-tests. All differences in soil organic carbon between cropland and native pasture and CRP and native pasture are significant at $P \leq 0.10$ as determined by paired t-tests.

density between land use treatments and published National Soil Survey Laboratory estimates at each location were seldom greater than 5%, indicating that soil compaction was not a factor affecting soil carbon stocks. Each core was separated into the following depth increments: 0 to 5 cm (0 to 2 in), 5 to 10 cm (2 to 4 in), 10 to 15 cm (4 to 6 in), 15 to 20 cm (6 to 8 in), 20 to 30 cm (8 to 12 in), 30 to 40 cm (12 to 16 in), 40 to 60 cm (16 to 24 in), 60 to 80 cm (24 to 32 in), 80 to 100 cm (32 to 40 in), 100 to 150 cm (40 to 60 in), 150 to 200 cm (60 to 80 in), 200 to 250 cm (80 to 100 in), and 250 to 300 cm (100 to 120 in).

Soil samples were returned to the laboratory and air-dried for 14 days. Following hand removal of visible plant material (plant crowns, residues, and roots), each soil sample was sieved, ground to pass through a 0.25 mm (0.01 in) screen, and stored in airtight plastic bags at room temperature to minimize microbial activity until analysis.

Soil samples were analyzed for organic carbon content using a dry combustion infrared instrumental procedure that differentiates organic and inorganic carbon on the basis of a sequential, two-stage temperature combustion (*8*). Volumetric contents of SOC were determined by multiplying the thickness of each individual depth increment by its bulk density and organic carbon concentration.

Locating replicate combinations of cropland, native pasture, and five-year- old CRP lands with similar soil characteristics at each location was not possible. Therefore, land uses at each location were treated as paired comparisons with the seven soil cores serving as replicates. Paired t-tests (CRP vs. cropland; CRP vs. native pasture; cropland vs. native pasture) were used to separate land use means within each location. Mean separation for the average of land uses across all locations was also determined with paired t-tests using location means as replications (20).

Results and discussion

Averaged across locations, SOC levels for CRP and cropland were significantly lower ($P \leq 0.10$) than those for native pasture to a depth of 100 cm (40 in), indicating that cultivation had markedly reduced SOC pools. Soil organic carbon losses due to cultivation averaged 61% in the surface 0 to 5 cm (0 to 2 in) increment and gradually declined with depth to lows of 15% for the 100 to 150 cm (40 to 60 in) increment. When compared to respective native pasture soils, SOC losses from sandy (Big Spring, Seminole, and Valentine) and loamy (Atwood and Colby) textured cropland soils were 59% and 42%, respectively, for the 0 to 40 cm (0 to 16 in) increment and decreased with depth to 14% and 7% for the 100 to 300 cm (40 to 120 in) increment (Tables 1, 2, 3, and 4). These losses are within the ranges reported by other researchers (*1,6,13,17,24*) and support the hypothesis that soils with low clay contents lose more SOC upon cultivation because clay is thought to protect organic matter from decomposition (*19,23,27*). The depletion of SOC with initial cultivation can be attributed to tillage induced changes in plant species composition, from perennial grasses to annual crop species (*21*), which reduce root biomass and inputs of carbon from roots to soils. Cultivation also increases soil temperature and microbial activity under periodically better aerated conditions which both increase organic matter decomposition and subsequent SOC losses (*28*).

Averaged across all locations, SOC levels for CRP plantings were significantly greater ($P \leq 0.10$) than those for cropland to a depth of 40 cm (16 in) (Tables 1 and 2). These results indicate that only five years after restoration of a perennial grass cover, 21% of the soil carbon lost during decades of intensive tillage had been replaced. In the 0 to 5 cm (0 to 2 in) depth increment, SOC levels for CRP land were 34% greater than those for cropland (Table 1). The magnitude of this difference declined with depth to 14% for the 30 to 40 cm (12 to 16 in) depth increment (Table 2). Elimination of tillage, reduced soil erosion, and accumulation of surface litter on CRP grass plantings are probably responsible for these differences. Consistent with our results are those of Blevins et al. (*5*), who showed that

Table 4. Mean organic carbon contents of the 100 to 300 cm soil profilesunder three contrasting land uses at selected Great Plains locations (Values in parentheses represent mean percent organiccarbon)

		Land Use		
Depth (cm)	Location	Crops	CRP	Native Pasture
		Metric tons C ha^{-1}		
100 to 150	Atwood	9.5(0.15)	9.4(0.14)	9.6(0.15)
	Colby	11.7(0.18)†	11.9(0.18)‡	15.6(0.24)
	Big Spring	6.9(0.08)†	7.2(0.09)‡	8.9(0.11)
	Seminole	7.9(0.09)	8.1(0.10)	7.9(0.10)
	Valentine	5.4(0.08)	5.8(0.08)	7.2(0.11)
	Mean	8.3(0.11)†	8.5(0.12)‡	9.8(0.14)
150 to 200	Atwood	6.6(0.11)	6.2(0.10)	6.6(0.11)
	Colby	7.6(0.12)	7.7(0.12)	7.9(0.13)
	Big Spring	3.8(0.05)	3.3(0.04)	4.3(0.05)
	Seminole	4.5(0.05)	5.0(0.06)	5.1(0.06)
	Valentine	3.9(0.05)	4.3(0.06)	4.3(0.06)
	Mean	5.3(0.07)	5.3(0.07)	5.6(0.08)
200 to 250	Atwood	6.2(0.09)	5.9(0.09)	6.1(0.09)
	Colby	7.0(0.10)	6.8(0.10)	7.4(0.11)
	Big Spring	3.4(0.04)	2.8(0.03)	3.8(0.04)
	Seminole	3.5(0.04)	4.0(0.04)	3.8(0.04)
	Valentine	3.3(0.05)	3.5(0.05)	3.4(0.05)
	Mean	4.7(0.06)	4.6(0.06)	4.9(0.06)
250 to 300	Atwood	5.9(0.09)	6.1(0.09)	6.0(0.09)
	Colby	6.0(0.09)	5.2(0.08)	5.5(0.08)
	Big Spring	2.5(0.03)	2.1(0.02)	2.6(0.03)
	Seminole	2.9(0.03)	3.7(0.04)	3.5(0.04)
	Valentine	1.9(0.03)	2.0(0.03)	2.1(0.03)
	Mean	3.8(0.05)	3.8(0.05)	3.9(0.05)

† Indicates differences in soil organic carbon between cropland and native pasture are significant at $P \leq 0.10$ as determined by paired t-tests.
‡ Indicates differences in soil organic carbon between CRP and native pasture are significant at $P \leq 0.10$ as determined by paired t-tests. No differences in soil organic carbon between cropland and CRP are significant at $P \leq 0.10$ as determined by paired t-tests.

after 10 years of no-tillage corn production, SOC for the surface 30 cm (12 in) was increased by 25% due to increased retention of surface litter and concomitant reductions in soil erosion.

Another factor contributing to observed differences in SOC between CRP and cropland may have been the greater root biomass associated with the establishment of perennial grasses (*21*). Although we did not quantify root biomass in the present study, other research indicates that mean annual carbon inputs to grassland soils are 90 to 800% greater than inputs into cultivated soils (*2,11,18*). Lynch and Whipps (*15*) suggest that rhizodeposition products (root residues, exudates, and exfoliates) within the rhizosphere of plants may account for up to 40% of the dry matter produced by plants. Similar observations (*2,11,15,18*) shown that rhizodeposition and root turnover associated with CRP grass plants have probably contributed to observed increases in SOC on CRP plantings, especially in the 5 to 40 cm (2 to 16 in) depth increment. From 40 to 150 cm (16 to 60 in) in depth, SOC levels for CRP land remained slightly higher than cropland (Tables 3 and 4), suggesting that within five years rhizodeposition products from CRP grass plantings are beginning to affect SOC content at these depths. Beyond 150 cm (60 in) in depth, however, SOC levels for CRP and cropland were similar (Table 4).

When compared to respective cropland soils, loamy textured CRP soils (Atwood and Colby) gained an average of 7.9 metric tons C ha^{-1} (7000 lbs C ac^{-1}) to a depth of 40 cm (16 in) and 9.0 metric tons C ha^{-1} (8000 lbs C ac^{-1}) to a depth of 300 cm (120 in), whereas sandy textured CRP soils (Big Spring, Seminole, Valentine) only gained 1.7 metric tons C ha^{-1} (1500 lbs C ac^{-1}) to a depth of 40 cm (16 in) and 4.3 metric tons C h^{-1} (3800 lbs C ac^{-1}) to a depth of 300 cm (120 in) (Tables 1, 2, 3, and 4). Only about 15% of the total carbon gain for loamy textured CRP soils occurred below a depth of 40 cm (16 in), while 60% of the total carbon gain for sandy textured CRP soils occurred below 40 cm (16 in) in depth. Sandy textured surface soils, by virtue of more frequent and complete wetting and drying cycles, better aeration, and lower water retention capacity relative to loamy textured CRP surface soils, exhibit enhanced organic matter decomposition rates which may reduce potential SOC gains in the upper 40 cm (16 in) of the soil profile (1,26). Despite differences due to texture, our results indicate that CRP lands have gained an average of 0.8 metric tons C ha^{-1} yr^{-1} (700 lbs C ac^{-1} yr^{-1}) to a depth of 40 cm (16 in) and 1.1 metric tons C ha^{-1} yr^{-1} (1000 lbs C ac^{-1} yr^{-1}) to a depth of 300 cm (120 in). These results are consistent with those of a simulation model developed by Cole et al. (9), suggesting that the 17 million ha (45 million acres) of cropland enrolled in CRP have sequestered about 45% of the 38.1 million metric tons C (84 billion lbs C) released annually into the atmosphere from United States agriculture, including nitrogen fertilizer manufacturing. These rates of carbon sequestration should not be expected to continue indefinitely, however, and unless there is a net increase in cropland withdrawn from cultivation every year, this soil carbon sink will gradually decline with time.

Although our data were limited to five locations within the southern, central, and northern Great Plains, they can reasonably be extrapolated to include the Great Plains where 72% of all CRP enrollments occur (*22*). It should be noted, however, that differences in the proportions of soil textures and moisture regimes between our sampling locations and the entire United States CRP enrollment may influence actual amounts of carbon sequestered. Irrespective of these considerations, our findings illustrate that agriculturally related CO_2 emissions may be effectively controlled through changes in land use and management systems.

Summary

Cultivation of prairie soils in Texas, Kansas, and Nebraska has resulted in marked declines in SOC content to a depth of 100 cm (40 in). Establishment of perennial grass cover under the

Conservation Reserve Program significantly increased SOC levels within five years when compared to adjacent croplands. Averaged across all locations, CRP soils gained 0.8 metric tons C ha^{-1} yr^{-1} (700 lbs C ac^{-1} yr^{-1}) to a depth of 40 cm (16 in) and 1.1 metric tons C ha^{-1} yr^{-1} (1000 lbs C ac^{-1} yr^{-1}) to a depth of 300 cm (120 in). The 17 million ha (45 million ac) of cropland enrolled in CRP may have the potential to sequester about 45% of the 38.1 million metric tons C (84 billion lbs C) released annually into the atmosphere by United States agriculture. These findings illustrate that agriculturally related CO_2 emissions may be effectively controlled through changes in land use and management systems.

[*Submitted October 1993; accepted March 1994.*]

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